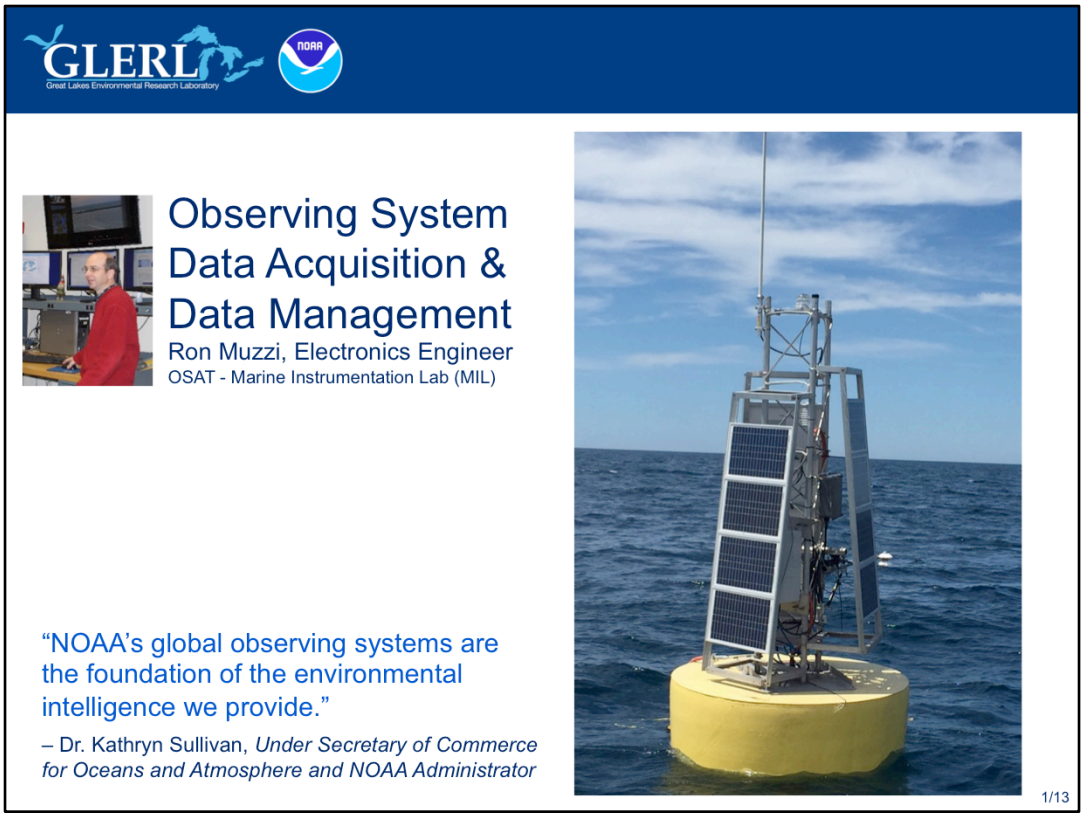

Photo: ReCON buoy in Lake Michigan, 7/29/2015 (All photos are NOAA photos, unless specified otherwise)

This work aligns with the following NOAA Goals:

Science: Climate Adaptation and Mitigation
Improved scientific understanding of the changing climate system and its impacts

Science: Weather-Ready Nation
Reduced loss of life, property, and disruption from high-impact events
Improve freshwater resource management
Improve transportation efficiency and safety
Healthy people and communities due to improved air and water quality services
A more productive and efficient economy through information relevant to key sectors of the U.S. economy

Science: Healthy Oceans
Improved understanding of ecosystems to inform resource management decisions
Recovered and healthy marine and coastal species
Healthy habitats that sustain resilient and thriving marine resources and communities
Sustainable fisheries and safe seafood for healthy populations and vibrant communities

Science: Resilient Coastal Communities and Economies
Resilient coastal communities that can adapt to the impacts of hazards and climate change
Comprehensive ocean and coastal planning and management
Safe, efficient and environmentally sound marine transportation
Improved coastal water quality supporting human health and coastal ecosystem services

Education: Science-Informed Society
Formal and informal educators integrate NOAA-related sciences into their curricula, practices, and programs

Education: Safety and Preparedness
Youth and adults from all backgrounds are aware of, prepare for, and appropriately respond to environmental hazards that impact health, safety, and the economy in their communities

Converting real world observations to data:

Observations

Sample Collection
remove from environment

Sensor
measure in environment

Remote Sensing
measure at distance from environment

Data

+ Location & Time

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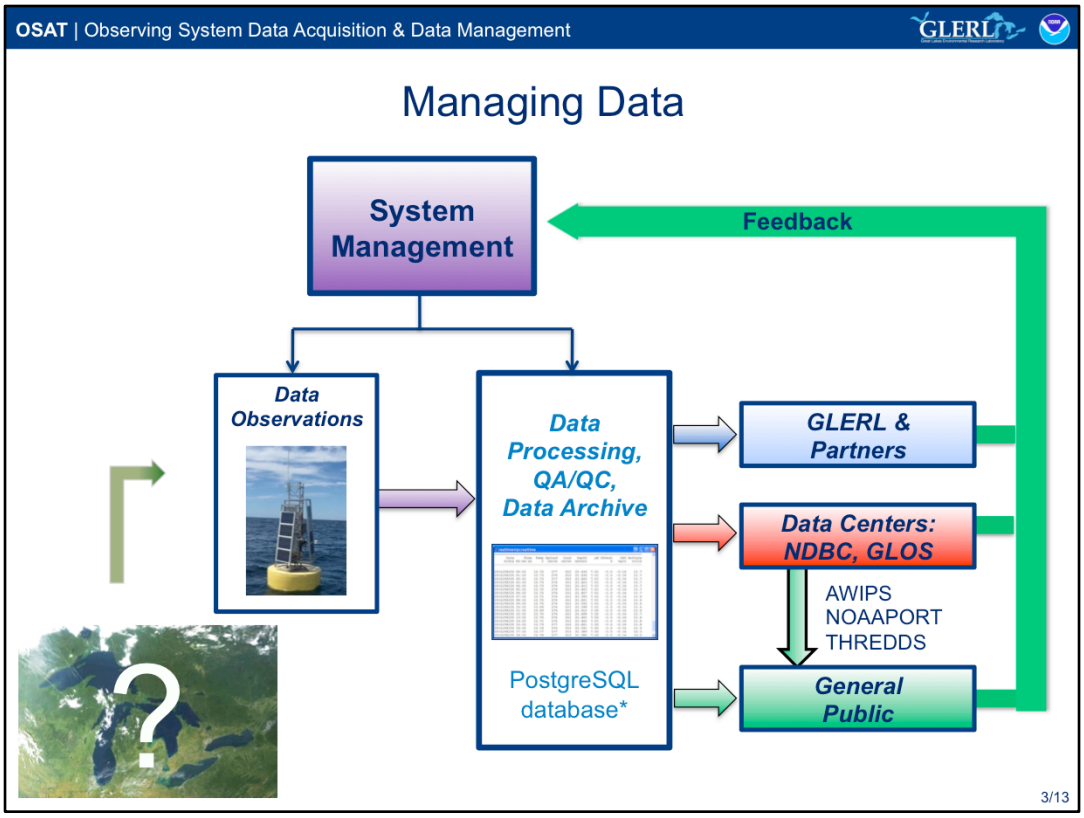
We're on the "front line" collecting the data from the Great Lakes
We'll focus on sensors, remote sensing will come in a later presentation



Data Observations – data collected from ReCON (Real-time Coastal Observation Network), moored instrumentation, etc.

Data Processing:
Quality control implemented through NDBC (National Data Buoy Center) protocols
Approved quality assurance plan for GLRI (Great Lakes Restoration Initiative) projects

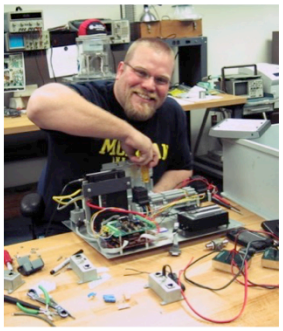
Database Management:
The OSAT team is updating our database to a PostgreSQL database for rapid storage and retrieval of real-time Great Lakes monitoring data. This will permit researchers to query the database for specific data, and allow the lab to produce publicly accessible websites with the data that are more responsive and efficient than the prior database.

GLERL & Partners – includes PI's (Principal Investigators), scientists, and institutions such as NWS (National Weather Service)

Data Centers – includes NDBC (National Data Buoy Center) and GLOS (Great Lakes Observing System); provides public real-time data access in the following formats:
AWIPS (Advanced Weather Interactive Processing System) – internet dissemination
NOAAPORT – Satellite dissemination
THREDDS (Thematic Realtime Environmental Distributed Data Services) – data and metadata database access from software
Web pages – general access from browsers

Getting the Data: Marine Instrumentation Lab (MIL)

- Expertise developed in-house through growing experience and long-term commitment
- MIL Capabilities:
  - Electronic & Mechanical Design
  - Software Development
  - Electronic/electrical construction
  - Mechanical construction & assembly
  - Prototype development
  - Testing, diagnostics, & calibration
  - Mooring design & fabrication
  - System assembly (buoys, platforms, etc.)
  - Handling and storage.



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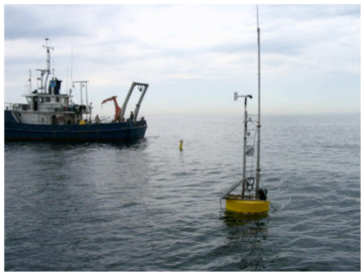
The MIL area can be viewed after the demonstration in the High Bay area following the morning presentations.

The priorities of the MIL team are to:
- Develop and prototype new and cutting-edge in-situ data collection techniques.
- Develop techniques to collect data year-round in the Great Lakes, including under-ice observations.
- Improve the efficiency of in-situ data collection.
- Improve the collection of real-time data for use by GLERL and its partners.

Working in the Field

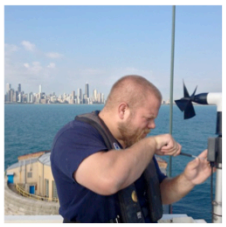
Deploy & Retrieve Moorings

Deploy & Retrieve Buoys



Work with Towed Vehicles, e.g. PSS

Work on Sensors on Navigational Structures



Work from Small Boats

- Full Access to Lakes, Buoys, Structures & Coastal Sites
- Collaborate with Coast Guard, Corp of Engineers, Historical Societies, Public & Private Parties

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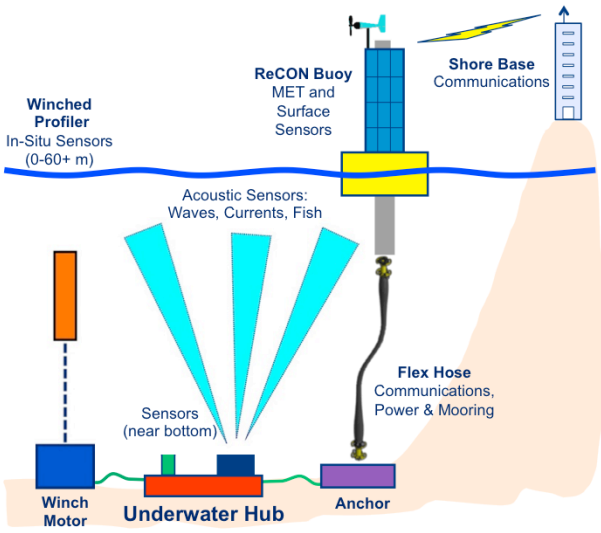
PSS = Plankton Survey System

Photos by GLERL:
Top Left – Tripod deployment in Lake Michigan off Muskegon
Bottom Left – ReCON buoy deployment in Lake Erie north of Cleveland
Left of Center – Towing the Plankton Survey System in Lake Michigan
Right of Center – White Shoal Light in northern Lake Michigan
Top Right – MET station maintenance on Chicago water intake crib
Lower Right – Deployment of ReCON underwater hub in Lake Erie north of Cleveland from small boat

OSAT | Observing System Data Acquisition & Data Management

ReCON: Realtime Coastal Observation Network

- Advanced data collection platform from buoys, underwater hubs, fixed structures, and coastal locations
- Buoys operate seasonally, fixed platforms operate year round
- Primarily powered by solar (wind or A/C when available)
- Embedded Linux platform for data processing, control, and diagnostics
- Sensors: MET, air/water quality, radiation, acoustic, image/video
- Guest ports allow platform use by others
- Multiple communications options provides **high bandwidth**, real-time data from seafloor back to lab



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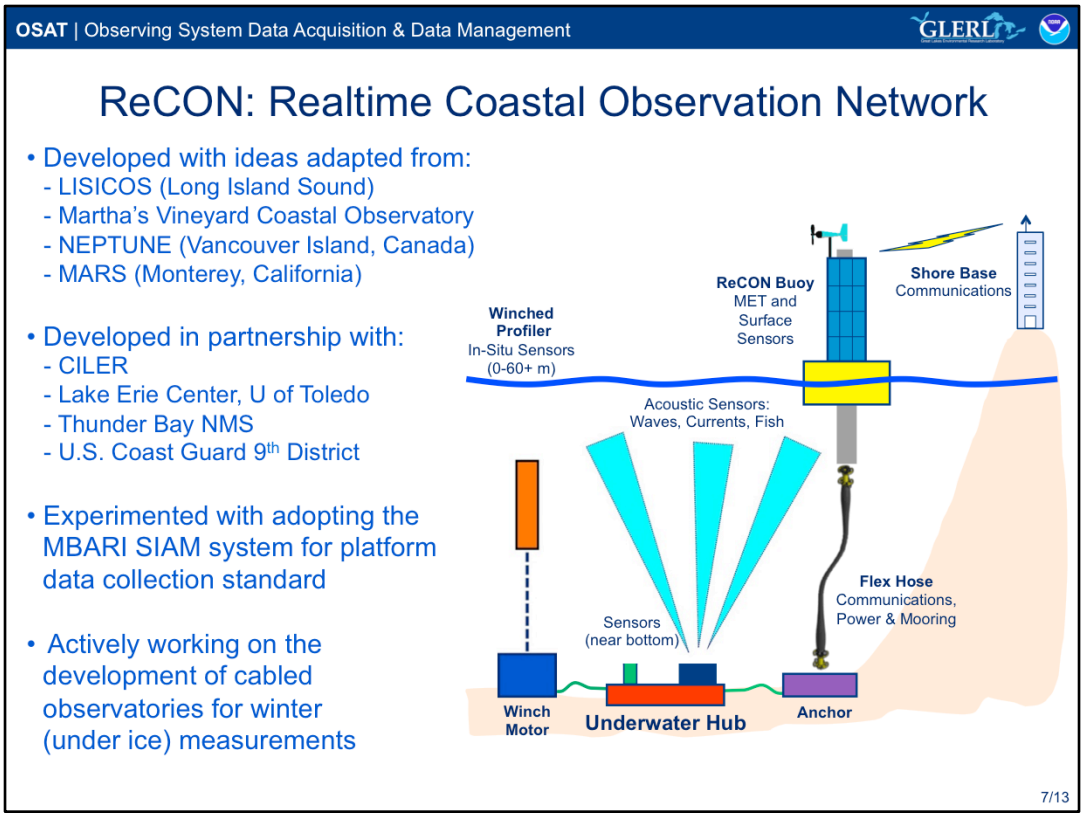
High bandwidth communications to lake floor:
- Allows real-time acoustics, video, and other high bandwidth data sensors
- Full power to lake floor systems

Communications options include private WiFi (for high bandwidth coastal applications), cell phone modem (low bandwidth coastal applications), or Iridium satellite (non-coastal sites)

MET = **met**eorological sensors, such as wind speed/direction, air temperature, relative humidity, dew point, rain



Developed with Ideas from:

Austin, T. C., J. B. Edson, W. R. McGillis, M. Purcell, R. A. Petitt, M. K. McElroy, C. W. Grant, J. Ware, and S. K. Hurst. 2002. A network-based telemetry architecture developed for the Martha's Vineyard Coastal Observatory. IEEE J. Ocean. Eng. 27**:** 228-234. 10.1109/joe.2002.1002477

Observatories:

LISICOS (Long Island Sound Integrated Coastal Observing System) is operated by the University of Connecticut, Department of Marine Sciences

Martha's Vineyard Coastal Observatory is operated by WHOI (Woods Hole Oceanographic Institute)

NEPTUNE (North East Pacific Time-series Undersea Networked Experiments) is located off Vancouver Island, Canada and was developed by the University of Victoria

MARS (Monterey Accelerated Research System) is located off Monterey, California, and is operated by MBARI (Monterey Bay Aquarium Research Institute)

Partnership List:

- CILER (Cooperative Institute for Limnology and Ecosystems Research)
- Lake Erie Center, University of Toledo
- Thunder Bay National Marine Sanctuaries & Underwater Preserve
- U.S. Coast Guard 9th District
- Great Lakes Water Institute, University of Wisconsin/Milwaukee, School of Freshwater Sciences
- ICON (Integrated Coral Observing Network), NOAA
- NASA Glenn Research Center
- NOAA High Performance Computing Center
- Ohio Supercomputer Center, Ohio State University
- Pier Wisconsin
- SEAKEYS (Sustained Ecological Research of the Florida Keys), Keys Marine Lab, Florida Institute of Oceanography

Sensor Management:

- MBARI (Monterey Bay Aquarium Research Institute) SIAM (Software Infrastructure and Applications for Monterey Ocean Observing System):

SIAM "consists of middleware and applications designed to enable automated platform configuration and data collection on sensor networks. SIAM has components to do data collection, archiving and telemetry."

quoted from SIAM web page, www.mbari.org/products/research-software/siam-documentation/

- SIAM supports the PUCK protocol (also developed by MBARI):

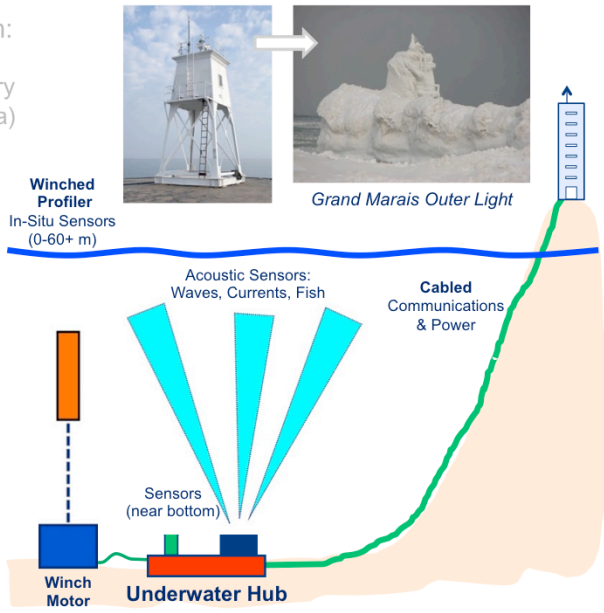
The PUCK protocol is basically a plug-and-play protocol to integrate sensors into on observation system.

"Managing sensor network configuration and metadata in Ocean Observatories using instrument pucks." Third

OSAT | Observing System Data Acquisition & Data Management

ReCON: Realtime Coastal Observation Network

- Developed with ideas adapted from:
  - LISICOS (Long Island Sound)
  - Martha's Vineyard Coastal Observatory
  - NEPTUNE (Vancouver Island, Canada)
  - MARS (Monterey, California)
- Developed in partnership with:
  - CILER
  - Lake Erie Center, U of Toledo
  - Thunder Bay NMS
  - U.S. Coast Guard 9th District
- Experimented with adopting the MBARI SIAM system for platform data collection standard
- Actively working on the development of cabled observatories for winter (under ice) measurements



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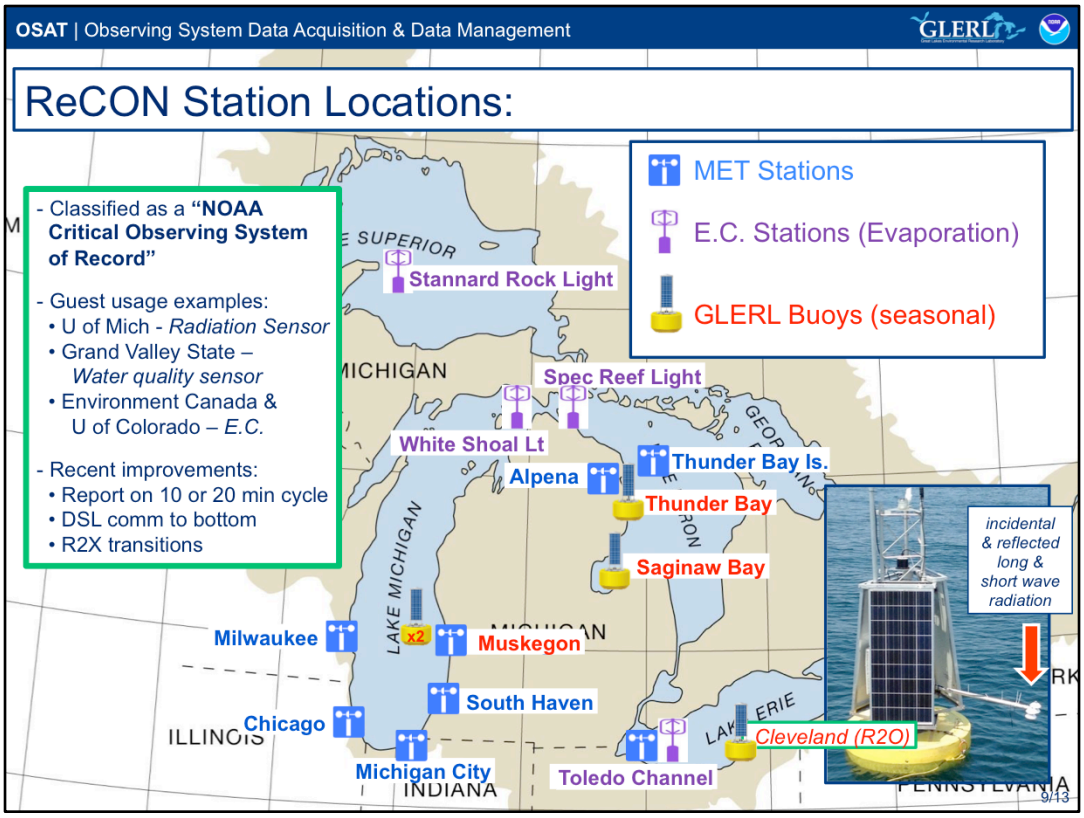
Some cabled observatory experience with cable laying & long distance DSL/power applications

Challenges include the land/water interface especially in ice conditions

Examples of Published Papers about ReCON Network:

RUBERG, S.A., E. Guasp, N. HAWLEY, R.W. MUZZI, S.B. BRANDT, H.A. VANDERPLOEG, J.C. LANE, T.C. MILLER, and S.A. CONSTANT. Societal benefits of the real-time coastal observation network (ReCON): Implications for municipal drinking water quality. *Marine Technology Society Journal* 42(3):103-109 (2008).
http://www.glerl.noaa.gov/pubs/fulltext/2008/20080057.pdf

RUBERG, S.A., S.B. BRANDT, R.W. MUZZI, N. HAWLEY, T. Bridgeman, G.A. LESHKEVICH, J.C. LANE, and T.C. MILLER. A wireless real-time coastal observation network. *EOS Transactions* 88(28):285-286 (2007).
http://www.glerl.noaa.gov/pubs/fulltext/2007/20070022.pdf



Map Notes:

MET (meteorological) stations are located on shore or on navigational structures.

E.C. (eddy covariance) stations measure evaporation. Requiring a fixed platform, they're located on off-shore navigational structures.

NOAA Critical Observing System of Record:

The ReCON network is classified by the NOAA Observing Systems Committee as a Critical Observing System of Record (SoR), which is defined as "an observing system that provides sustained critical observations for long-term research and/or operations," and critical is defined to mean that "the degradation or loss of the SoR would have significant impact on NOAA's mission (including federated and international commitments)." cf. https://nosc.noaa.gov/OSC/oss.php

Guest Usage Examples:

- U of Mich Radiation Sensor is an experiment to measure eddy covariance from a buoy to estimate evaporation over the water, deployments in Cleveland & Muskegon
- We host the Grand Valley State University water quality sensor since the university doesn't have their own buoys to make these measurements in Lake Michigan
- The U of Colorado & Environment Canada eddy covariance stations are co-located with our ReCON boxes to provide realtime measurements (Stannard Rock in Lake Superior, White Shoal Light in Lake Michigan, and Spectacle Reef Light in Lake Huron)

Improvements:

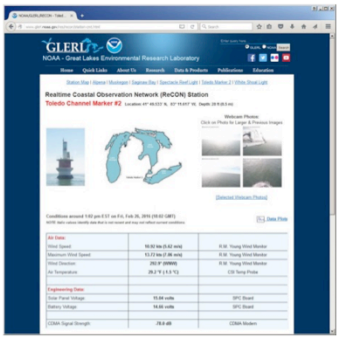
- The typical one hour data cycle has been increased to 20 minutes for buoys (wave measurements are on a 20 minute cycle) and 10 minutes for most other stations
- DSL (Digital Subscriber Line) is a communications protocol to transmit high bandwidth ethernet data over distances of 1000's of feet

R2X Transitions:

- R2O: The Cleveland Buoy ReCON station in 2015 was fully transitioned—deployment, operation, and maintenance—to GLOS
- R2C: The System Power Controller (SPC) board developed by GLERL, now commercially manufactured based on the GLERL open source design
- R2C: Technology from the ReCON buoy has been used in the development of commercial buoys for the Great Lakes and other lakes:

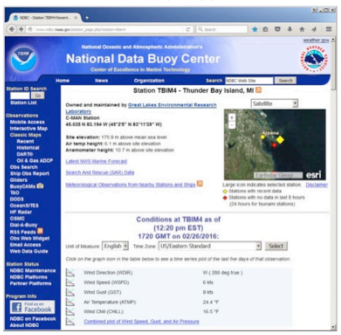
Data Access – Public Web Sites

GLERL Web



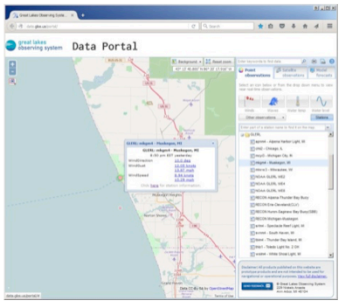
www.glerl.noaa.gov/metdata
www.glerl.noaa.gov/res/recon

NDBC Web



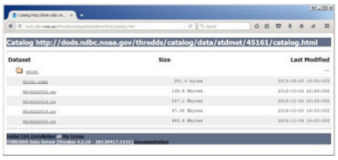
www.ndbc.noaa.gov

GLOS Web



www.data.glos.us/portal

NDBC THREDDS



dods.ndbc.noaa.gov/thredds/catalog.html

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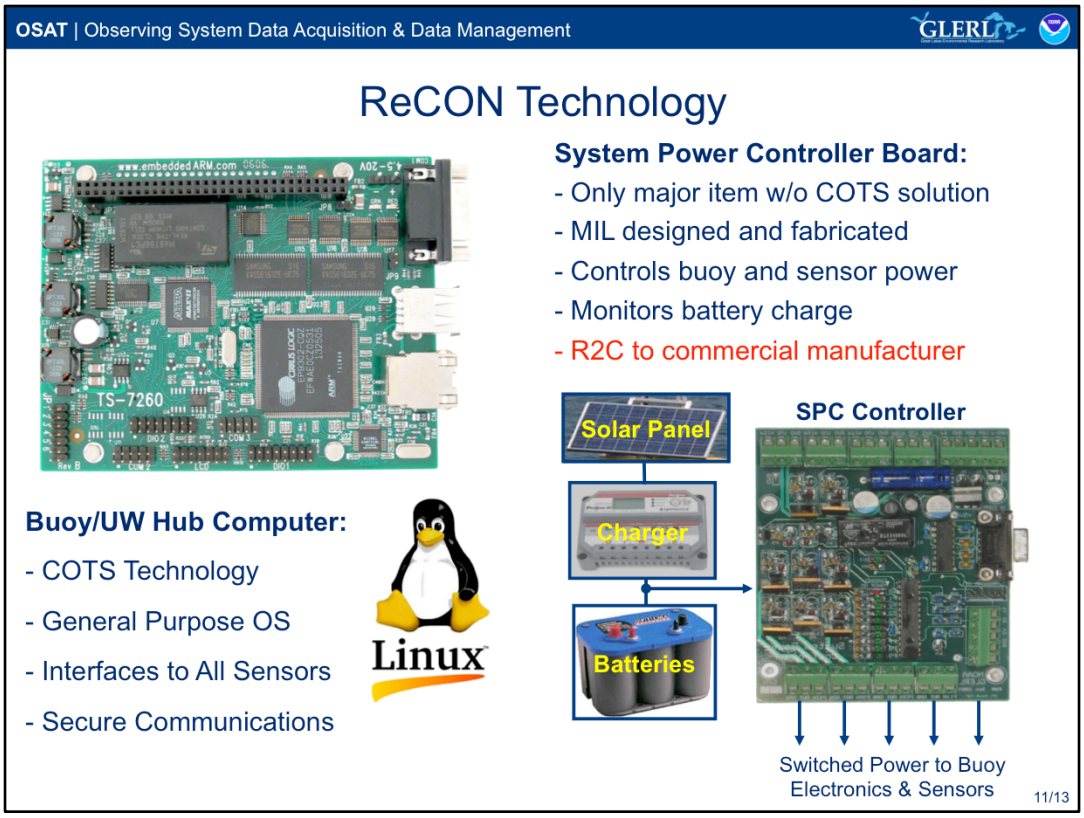
Various other database formats are available to researchers to GLERL and partners, i.e., PostgreSQL



Buoy/Underwater Hub Computer:

COTS (Commercial, Off-The-Shelf) Technology:
- Economical and cutting edge
- Industrial grade, not consumer grade
- ARM Processor leverages smartphone technology
- PC104 form leverages embedded application technology - readily available stackable add-on modules

General Purpose OS (Operating System):
- Linux operating system – the penguin is the Linux mascot!
- Multi-tasking - simultaneous sampling, processing, data uploading, remote access
- Diagnostics - multiple operating system tools, debugging
- Any language - C, java, perl, kermit, matlab, etc.
- Onboard advanced data processing - intelligent, adaptive data collection and QA/QC

Interfaces to All Sensors:
- Supports various serial, ethernet, and USB sensor interfaces
- With data logger (Campbell Scientific series) supports analog and SDI sensors
- With intelligent programing, can interface to sensors not designed for real-time use

Secure Communications to Lab:
- Two-way communications from lab to the underwater hub & sensors
- Allows reconfiguration (or correcting mis-configurations) & diagnostics of sensors
- Communication tunnel is encrypted for secure access over the internet

System Power Controller (SPC) Board:
- Only major item without COTS solution
- MIL designed and fabricated
- Switches, monitors, and controls power to all buoy components and sensors
- Monitors battery charge and discharge
- R2C → now commercially manufactured by SeaView Systems

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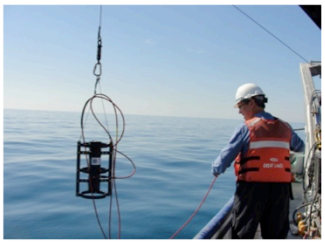
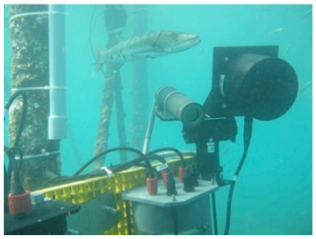
Other Observations/Data Collections:

- Long Term Research (LTR) moorings:
  Yearly temperature profiles
- Moorings for specific projects:
  Muskegon, W. Lake Erie, Mackinac Straits
- Buoys for specific projects:
  HABs, hypoxia, spill response
- Future projects in development:
  - Acoustics (active/passive)
  - Cabled observatories
  - Winched profiler

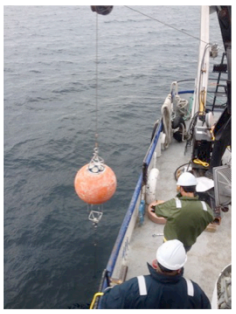
LTR Mooring Locations



UV Radiometer in Lake Michigan



Acoustics Prototype Testing in the Florida Keys



ADCP in Straits of Mackinac

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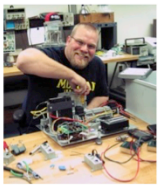
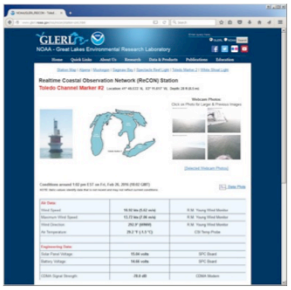
LTR Moorings:

- Southern Lake Michigan mooring is our longest continuous year-round data record, collecting for over 30 years
- Other LTR moorings include Northern Lake Michigan, Lake Huron, etc.

HABs – Harmful Algae Blooms

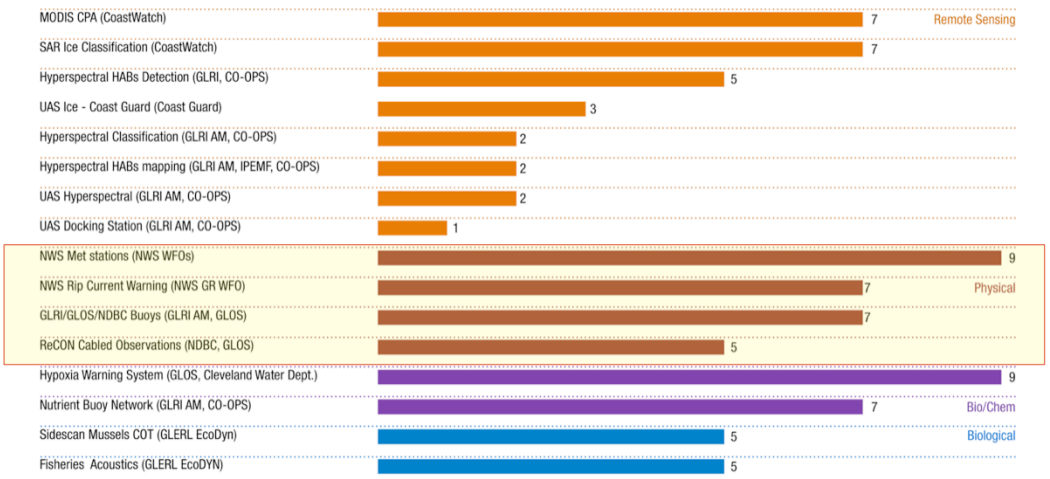
Questions or Feedback?





OSAT | Observing System Data Acquisition & Data Management

Technical Readiness Level of OSAT Products



Technical Readiness Level (TRL) Definitions

1: Basic principles have been observed and reported.

2: Technology concept and/ or application has been formulated.

3: Analytical and experimental critical function and/or characteristic proof-of-concept.

4: Component/subsystem validation in laboratory environment.

5: System/subsystem validation in relevant environment.

6: System/ subsystem model or prototyping demonstration in a relevant end-to-end environment.

7: System prototyping demonstration in an operational environment.

8: Actual system completed and "mission qualified" through test and demo in operational environment.

9: Actual system "mission proven" through successful operations.

Additional Information